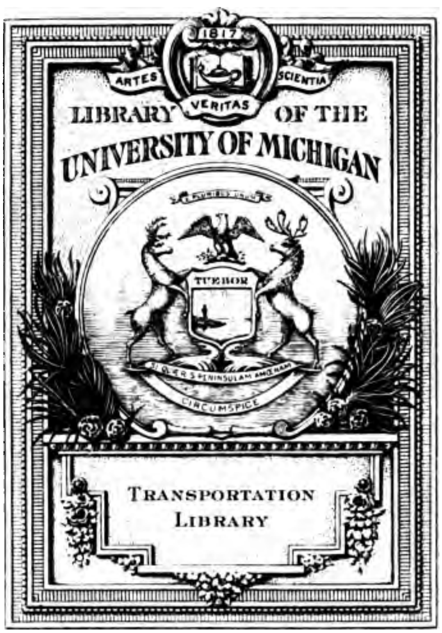
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INVESTIGATION

OF THE

POWER CONSUMED IN OVERCOMING

THE

INERTIA OF RAILWAY TRAINS,

AND OF THE

RESISTANCE OF THE AIR

TO THE

MOTION OF RAILWAY TRAINS

AT HIGH VELOCITIES.

BY

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POWER CONSUMED IN OVERCOMING
THE
INERTIA OF RAILWAY TRAINS,
ETC.

THE amount of power consumed in overcoming the inertia of railway trains is at present very imperfectly known; but the knowledge of it is practically of great utility in adapting the construction of locomotive engines to the circumstances of gradient, character of traffic, &c., in lines where they differ; and also equally useful where stationary power of any kind is used*. I have been led to the consideration of these subjects from their relation to questions upon which I have been required to report in the capacity of Engineer to the South-Eastern Railway, and have been induced to publish the results with the hope of producing some advance in the knowledge of these subjects, which are of the highest national importance, as affecting the railway communication of the country.

The action of a locomotive is of a much more complicated character than that of any other steam-engine, and the construction and arrangement of the parts by

* The Author has been indebted to Mr. E. Rutland, without whose valuable assistance he would not have been enabled, for want of time, to make the necessary calculations.

which the greatest mechanical effect is produced is a problem of much greater difficulty than any that occurs in the construction of stationary engines—in fact, as the time since the invention of the locomotive has been too short to bring it to that perfection which may be expected after further experience, it may be looked upon, in its present state, as a very imperfect machine, although the most beautiful application of the power of steam.

The essential difference in the action of the locomotive, as compared with other engines, is produced by the circumstance of the traction force being required to be maintained at so great a variety of speeds, extending to a velocity of four or five times that of an ordinary engine; and the supply of steam being required to be in proportion to the velocity, it is evident that the boiler, as well as all other parts of the engine, have a duty to perform of a much more difficult and delicate character than those of an ordinary steam-engine.

The object of the first step in this investigation is to ascertain the degree of resistance the engine is required to overcome under different circumstances, viz.:—

In getting the train in motion from a state of rest; and from the atmosphere when in motion; the correct knowledge of which is necessary in order to determine the amount of power lost in each case.

The time lost in the passage of trains, by making frequent stoppages, is rendered sufficiently evident by the difference in the rate of travelling in the new system of express trains as compared with the stopping trains, but the amount of this loss of velocity is deserving of more serious consideration than has hitherto been

given to it; and locomotive engines for stopping trains should be constructed to have more tractive power than those for express trains, although in the latter a large evaporating power of boiler is most important.

The tractive power of the locomotive necessarily becomes less as the velocity increases; but the amount of this loss it is difficult to ascertain, from the law of the resistance of the air at different velocities not having been established. Observed velocities on the Atmospheric Railway will much assist this investigation of the resistance of the air, because the tractive power here remains nearly constant at all velocities, and is not subject to reduction as on the locomotive line, from deficiency of steam and increase of back pressure from the blast-pipe; and in a subsequent part of the paper this subject will be treated of more fully. It is, however, desirable in the first place to ascertain the power required to overcome the inertia of the train, and the velocities acquired, which, when understood, assists the calculation of the resistance of the air, by enabling a comparison to be made of the observed and the calculated accelerating forces.

The velocity which a train would acquire in a given distance (assuming a constant and equal propelling force, and that the resistance is constant at all velocities) can be obtained by the established dynamical law of constant accelerating forces, which will be familiarly illustrated by the velocity acquired being that of a body falling the given distance on an inclined plane, whose length is represented by the whole weight of the train, and altitude by the moving or accelerating force.

Let A represent the area of section of an atmospheric pipe or cylinder of a locomotive.

P the pressure in the per square inch (equal half the vacuum in inches).

T the weight of the train in pounds.

S the length of the plane.

$\frac{1}{I}$ the inclination of the plane.

f the friction of the train per ton.

Then A P = total pressure on the piston.

$\frac{T}{I}$ = pounds resistance from gravity.

$\frac{T}{2240}f$ = pounds resistance from friction.

$A\ P \pm \frac{T}{I} - \frac{T}{2240}f$ = moving force in pounds.

$\dfrac{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}{T}$ = inclination of the plane,

on which a body without friction would descend with equal velocities and in equal times.

$\left(\dfrac{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}{T}\right) S$ = perpendicular height through which a body must fall to acquire the same velocity.

Then by the law of constant accelerating forces, V = the velocity in feet per second, is

$$2\sqrt{\left(\dfrac{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}{T}\right) S\ 16\tfrac{1}{3}}$$

and t = the time in seconds $2\sqrt{\left(\dfrac{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}{T}\right) S\ 16\tfrac{1}{3}}$

$$\left(\dfrac{T}{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}\right) \frac{1}{32\frac{2}{3}} \text{ or } t = \left(\dfrac{T}{A\ P \pm \frac{T}{I} - \frac{T}{2240}f}\right) \frac{V}{32\frac{2}{3}}$$

Having thus obtained the height through which a body must fall to acquire a velocity equal to that of the train at the end of a given distance, the time required to move a given train any given distance will, of course, be readily obtained, assuming there is no loss of the total effective pressure from friction or otherwise, or increased resistance from the increased velocity through the atmosphere.

The following Table shows the theoretical velocities which would be acquired by trains varying from 25 to 200 tons on a level railway with moving forces varying from 2000 to 4000 lbs.; allowing 8 lbs. per ton friction, but no loss from increased resistance of the air at higher velocities.

TABLE No. 1.

	Tractive Force 2000 lbs.	Tractive Force 2500 lbs.	Tractive Force 3000 lbs.	Tractive Force 3500 lbs.	Tractive Force 4000 lbs.
			TRAIN OF 25 TONS.		
Velocity at ½ mile	50.456	57.235	63.06	68.	73.548
" 1 mile	71.4	80.9	89.202	96.157	104.012
" 1½ mile	87.556	99.00	109.24	117.776	127.391
" 2 miles	101.116	114.43	126.153	136.	147.085
			TRAIN OF 50 TONS.		
Velocity at ½ mile	33.68	38.59	42.93	46.933	50.55
" 1 mile	47.668	54.61	60.73	66.336	71.49
" 1½ mile	58.38	66.89	74.378	81.287	87.55
" 2 miles	67.41	77.24	85.897	93.866	101.10
			TRAIN OF 75 TONS.		
Velocity at ½ mile	25.73	29.947	33.69	37.019	40.106
" 1 mile	36.407	42.377	47.66	52.36	56.725
" 1½ mile	44.58	51.91	58.38	64.124	69.48
" 2 miles	51.489	59.92	67.41	74.038	80.203
			TRAIN OF 100 TONS.		
Velocity at ½ mile	20.617	24.548	27.93	30.94	33.69
" 1 mile	29.199	34.748	39.5	43.76	47.66
" 1½ mile	35.74	42.54	48.38	53.61	58.38
" 2 miles	41.28	49.13	55.86	61.88	67.38
			TRAIN OF 150 TONS.		
Velocity at ½ mile	13.72	17.51	20.57	23.26	25.73
" 1 mile	19.42	20.77	29.13	33.01	36.4
" 1½ mile	23.78	30.34	35.68	40.33	44.58
" 2 miles	27.499	35.06	41.2	46.52	51.46
			TRAIN OF 200 TONS.		
Velocity at ½ mile	8.377	12.60	15.73	18.34	20.61
" 1 mile	11.832	17.82	22.26	26.01	29.15
" 1½ mile	14.51	21.84	27.29	31.89	35.74
" 2 miles	16.8	25.62	31.5	36.68	41.22

In practice, these velocities will not be obtained with the locomotive engine from the loss of tractive power, from deficiency of steam and from back pressure in addition to the atmospheric resistance. As in the atmospheric railway, this will be the principal resistance; it will be interesting to compare the velocity calculated from the formula with those obtained in practice, which we can do by the experiments of Mr. Stephenson on the Dalkey Line which were registered with great care and accuracy. These are given in the following table :—

TABLE No. 2.

TABLE showing the observed Velocities at the end of each Plane on the DALKEY LINE, and those which would have been obtained had there existed no loss from Friction of the Piston, Resistance of the Air, &c.

		Experiment No. 7. Train 34.7 Tons.			Experiment No. 12. Train 45.5 Tons.			Experiment No. 15. Train 53.5 Tons.			Experiment No. 16. Train 55.8 Tons.			Experiment No. 17. Train 58. Tons.			Experiment No. 19. Train 63.2 Tons.			Experiment No. 20. Train 64.7 Tons.		
Inclination.	Length in Chains.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.	Observed Velocity.	Calculated Velocity.	Difference.
1 in 166	28	20.0	25.5	5.5	17.2	22.3	5.1	15.0	20.6	5.6	12.9	16.8	3.9	15.0	20.4	5.4	13.4	17.2	4.8	12.0	15.6	3.6
1 in 218	8	21.2	29.5	8.3	20.0	25.5	5.5	16.4	23.8	7.4	13.4	19.8	6.4	16.4	23.6	7.2	14.4	19.8	5.4	13.4	18.7	5.3
1 in 104	10	22.5	32.7	10.2	20.0	27.8	7.8	19.0	25.4	6.4	13.4	20.9	7.5	17.2	25.3	8.1	15.0	20.8	5.8	12.9	19.5	6.6
1 in 139	4	22.5	34.2	11.7	20.0	29.0	9.0	17.2	26.3	9.1	14.4	22.0	7.	17.2	26.5	9.3	13.9	21.4	7.5	13.4	20.2	6.8
1 in 100	8	25.7	36.3	10.6	21.2	30.5	9.3	18.0	27.4	9.4	13.9	22.7	8.8	17.2	27.4	10.2	14.4	22.1	7.7	13.4	20.8	7.4
1 in 131	12	25.7	40.3	14.6	24.0	33.8	9.8	19.0	28.8	9.8	15.0	24.8	9.8	18.0	28.6	10.6	15.7	24.2	8.5	13.9	22.4	8.5
1 in 211	6	27.7	42.4	14.7	24.0	35.6	11.6	20.0	30.3	10.3	15.0	26.1	11.1	18.0	31.2	13.2	15.0	25.0	10.0	13.9	23.0	9.1
1 in 115	24	30.0	47.8	17.8	27.7	40.2	12.5	24.0	34.4	10.4	20.0	30.0	10.0	21.2	33.4	12.2	15.7	26.	11.3	18.0	26.5	8.5

From an examination of the Table it will be seen that in the length of the line, $1\frac{1}{4}$ miles, the loss of velocity was about one-half the observed velocity, both with the light and heavy loads, arising from the loss of moving force by friction of the piston, resistance of the air, &c.

I have also given, in the following Table, a number of observations on locomotive lines of the acceleration from a state of rest, which are compared with the calculated velocities, as in the atmospheric experiments.

In the computation of the accelerating force the effect of the inclination is deducted, and 8 lbs. per ton for friction, but no deduction is made for the resistance of the air.

TABLE No. 3.

Distances.	No. 1. South-Eastern Railway. Weight of Train, 68 Tons. Cylinder, 14 inches. Length of Stroke, 18 inches. Driving-wheel, 5 feet 6 inches.			No. 2. South-Eastern Railway. Weight of Train, 78 tons. Cylinder, 14 inches. Length of Stroke, 21 inches. Driving-wheel, 5 feet 6 inches.			No. 3. South Eastern Railway. Weight of Train, 120 Tons. Cylinder, 14 inches. Length of Stroke, 18 inches. Driving-wheel, 5 feet 6 inches.			No. 4. South-Eastern Railway. Weight of Train, 84 Tons. Cylinder, 14 inches. Length of Stroke, 21 inches. Driving-wheel, 5 feet 6 inches.			No. 5. South-Eastern Railway. Weight of Train, 72 Tons. Cylinder, 14 inches. Length of Stroke, 18 inches. Driving-wheel, 5 feet 6 inches.		
	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.
		m. sec.	miles		m. sec.	miles		m. sec.	miles		m. s.	miles		m. s.	miles
Started	Rising 1 in	16 0		Rising 1 in	7 15		Rising 1 in	26 30		Rising 1 in	2 40 3 30		Falling 1 in	0 25 1 5	
¼ Mile......	264	17 15	10.0	264	7 50	12.	264	27 55	10.6	264	4 6 4 34	12.6	264	1 30 50	18.0
½ "	...	18 16	13.6	...	8 45	16.3	...	29 30	20.0	...	4 56 5 17	20.5	...	2 8 24	25.0
¾ "	...	19 4	18.8	...	9 25	22.5	...	30 12	21.4	...	5 25 51	25.0	...	2 39 54	30.0
1 Mile......	...	19 44	22.5	...	10 5	22.5	...	30 50	23.6	...	6 8 25	26.5	...	3 9 22	31.0
¼ "	...	20 20	25.0	...	10 40	25.7	...	31 27	24.3	...	6 39 54	32.4	...	3 36 49	32.1
½ "	...	20 53	27.4	...	11 13	27.4	...	32 2	25.6	...	7 7	34.7	...	4 3 14	32.1
¾ "	...	21 55	29.0	...	11 46	27.4	...	32 33	29.0	...	...	...	...	4 26 37	37.0
2 Miles......	...	22 25	30.0	...	12 20	26.5	...	33 4	29.0	...	. .	...	...	4 49	40.0
¼ "	...	22 55	30.0	...	12 53	27.4									
½ "	...	23 25	30.	...	13 25	28.1									
½ "	...														

Distances.	No. 6. NarrowGauge Engine (Bodmer's). Weight of Train, 66 Tons. Cylinder, 16 inches. Stroke, 2 feet 6 inches. Driving-wheel, 5 feet 6 inches.			No. 7. GreatWestern RailwayEngine. Weight of Train, 113 Tons. Cylinder, 15¾ inches. Stroke, 20 inches. Driving-wheel, 7 feet.			No. 8. The same Engine and Load returning from Didcot.			No. 9. The same Engine with a gross Load of 94 Tons.			No. 10. Grand Junc. Railway Engine. Weight of Train, 117 Tons. Cylinder, 14¼ inches. Stroke, 20 inches. Driving-wheel, 6 feet.		
	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.	Inclination.	Time.	Observed Velocity.
		m. sec.	miles		m. sec.	miles		m. se .	miles		m. sec.	miles			miles
Started		11 0			1 11						7 10				
¼ Mile......	Rising 1 in	12 2	16.6	Nearly	2 40	13.1	Nearly			Nearly	8 0	18.0	Falling 1 in		12.5
½ "	264	12 40	28.0	Level.	3 49	25.0	Level.	...	14.0	Level.	40	22.5	300	...	19.1
¾ "		13 10	32.1		4 25	28.1	...	...	25.6	...	9 12	28.1	...	...	24.3
1 Mile	...	13 40	32.1	...	57	33.3	...	7 15	30.0	...	40	32.1	...	...	27.3
¼ "		14 7	33.5		5 24	33.25	...	42	33.3	...	10 5	36.0	...	...	30.0
½ "		...	33.5		6 0	33.31	...	8 5	40.9	...	29	39.2	...	...	31.0
¾ "		...	...		29	34.6	...	27	40.9	...	52	37.5	...	...	34.6
2 Miles......	...	...	...	...	55	34.6	...	47	45 0	...	11 12	45.0	...	...	34.6
¼ "		...	...		7 21	36.0	...	9 8	42.8	...	33	42.8	...	...	36.0
½ "		...	...		46	41.0	...	27	47.4	...	54	42.8	...	...	36.0
¾ "		...	...		8 8	42.9	...	46	47.4	...	12 13	47.3	...	...	37.5
3 Miles......	...	...	...	...	29	41.0	...	10 4	50.0	...	32	47.3	...	...	36.0
¼ "		...	...		51	45.0	...	21	53.0	...	51	47.3	...	...	...
½ "		...	...		9 11	45.0	...	38	53.0	...	13 9	50	...	...	...
¾ "		...	...		31	45.0	...	55	53.0	...	27	50.0	...	...	...
4 Miles......	...	...	...	...	51	47.4	...	11 12	53.0	...	45	50.0	...	...	...
¼ "		...	...		10 10	47.4	...	29	53.0	...	14 1	56.3	...	...	...
½ "		...	...		29		...	46	53.0	...	...	...	...	...	...
¾ "		...	...		11 6	49.0	...	12 2	56.0	...	...	...	...	...	...
5 Miles......	...	...	...	...	25		...	19	60.0	...	...	...	...	...	...

In these locomotive results, it is more difficult to estimate the actual tractive force, because we have not, as in the atmospheric railway, the actual direct propelling force on the train; it can only be obtained from the pressure of the steam in the boiler, which may be much diminished before it reaches the piston, and there is also loss from friction in the transmission of the power to the driving-wheel.

In estimating the accelerating force by which I derive the theoretical velocities, I have allowed the steam in the cylinder to average $\frac{5}{6}$ths of that in the boiler, without any deduction for the friction of machinery; and it is apparent, from the observed velocities below 30 miles per hour, that this deduction is sufficient within that velocity, and we obtain this important practical result, "That the lost power of the locomotive engine below the speed of 30 miles is so small as to be scarcely appreciable, and that the time and power which is absorbed to put trains into motion is almost entirely required to overcome the inertia of the train, and is not the result of any loss or imperfection of the engine."

This will be more decidedly shown by calculating the moving force due to the time consumed in moving the trains over the measured distances from a state of rest which I have estimated in all the cases where the distances are known accurately.

In No. 4 Experiment, a train of 84 tons was moved a distance of 2640 feet from a state of rest in 136 seconds up an incline of 1 in 264. The moving force here expressed is 1664 lbs., which added to 1405 lbs. (the resistance from friction and gravity) gives a sum of

3069 lbs. which is nearly equal to the whole tractive force of the engine.

In No. 5 Experiment, a train of 72 tons was moved a distance of 2640 feet in 103 seconds from a state of rest down an incline of 1 in 264. The accelerating force here is 2443 lbs., from which 35 lbs. have to be deducted from the effect of the inclination and friction, making the tractive power excited by the engine 2408 lbs.

In No. 6 Experiment, a train of 66 tons was moved the same distance up an incline of 1 in 264 in 100 seconds, which expresses a tractive power of the engine of 3508 lbs., of which 2420 lbs. are the accelerating force.

In the Great Western down Experiment, made by the Gauge Commission, the train started from an even mile post, and I have the time of the first half-mile 105 seconds. The moving force which would move 113 tons the distance of 2640 feet from a state of rest in 105 seconds is 3690 lbs., or with the addition of friction fully equal to the whole tractive power of the engine, shewing most distinctly that the whole power is effective.

Several other instances might be given; but they all tend to shew there is little loss in the tractive power of the locomotive from friction and loss of effective steam pressure in velocities under 30 miles per hour.

POWER REQUIRED TO OVERCOME THE INERTIA OF TRAINS.

The first view of the question of the power required in the traction of a train over a given distance with a

locomotive engine when frequent stoppages are necessary, as compared with running throughout, would not lead to the conclusion that any power is lost by the stoppages, because a given load is moved over an equal space in both cases, or, in other words, the same number of cylinders full of steam will be consumed in each of the cases. This is, however, an erroneous view of the subject; because it assumes that the train has a constant accelerating force, which is not the fact in practice, or the power required would be the same in each case. The trains whether stopping or not would continue to accelerate to the end of the journey, and the sum of the acceleration or total lost power would be the same in both cases, as well as the amount of power expended.

The fact in practice is that the trains do not accelerate beyond a certain speed, because the tractive power of the engine becomes less, and the resistance of the air greater, as the velocity increases; the limit to the velocity being that when the force and resistance balance.

In the atmospheric railway, this acceleration continues longer, because there is little variation in the tractive force; and there is little doubt that with sufficient length of pipe speed much exceeding that of the present locomotive may be obtained.

With the locomotive the tractive force falls off rapidly when exceeding a certain speed, which will vary with the proportions of the parts of the engine, and the quantity of steam consumed during the acceleration or getting up the speed is much greater over a given length than when running at full speed; and hence there is more power required in conveying a stopping *train* than in one running throughout, although the

same number of cylinders full of steam are used in each case. The difference of steam used would not, however, be a correct representation of the power consumed, because the amount of effective power is not in proportion to the steam used, being greater at a low velocity than at high ones; but the proportion is not sufficiently known to form a basis for calculation, and this method of arriving at the result will be quite unnecessary, as the power required to overcome the inertia must be simply the tractive force multiplied by the length required to acquire the given velocity.

This must be too evident to require explanation, but it will be seen quite clearly in the consideration of the case of the retarding force required to bring a train which has acquired a certain momentum to a state of rest, a case which would be represented in practice by a plane whose inclination balances the friction.

If we conceive the case of the plane being level, and the accelerating force equal to double the retardation from friction and resistance of the air, the time and distance a train would require to come to a state of rest would be exactly equal to that required to bring it to any given velocity, and one-half the useful mechanical effect would be lost by the necessity of bringing the train to a state of rest at any given point.

In order to illustrate the actual loss in practice from the power necessary to overcome the inertia of trains, I have calculated the horse power required in each of Mr. Stephenson's experiments on the Dalkey Line, from which it will be seen that in several instances above

one-fifth of the whole power excited by the engine had been employed to overcome the inertia of the train.

TABLE No. 4.

No. of Train.	Train. Weight.	Friction and Gravity.	Maximum Uniform Velocity.	Vacuum Tube. Height of Barometer.	Pressure of Vacuum.	Area.	Total Power of working Air Pump.	Power to overcome the Inertia of Trains.
No.	Tons.	lbs.	Miles per hour.	Inches.	lbs. per sq. inch.	Square Inches.	Horse power.	Horse power.
4	26.5	781	34.7	18.5	9.2	176.7	332	72
5	30.8	907	32.0	19.0	9.5	176.7	336	70
7	34.7	1023	29.0	20.0	10.0	176.7	454	66
8	36.8	1084	28.3	20.7	10.4	176.7	350	67
9	38.3	1129	28.3	21.0	10.5	176.7	381	69
10	42.5	1253	25.7	22.1	11.0	176.7	389	63
11	43.8	1292	25.3	22.5	11.2	176.7	386	63
12	45.5	1341	25.2	22.7	11.3	176.7	427	65
14	51.0	1503	22.7	23.3	11.6	176.7	396	60
15	53.5	1576	21.7	24.0	12.0	176.7	460	57
17	58.0	1709	20.4	23.8	11.9	176.7	506	55
18	59.8	1763	18.0	23.6	11.8	176.7	390	44
20	64.7	1907	17.6	24.4	12.2	176.7	415	46

Note.—The experiments estimated are Nos. 7, 12, 15, 16, 17, 19, and 20, which are the only ones where the vacuum was sufficiently uniform to enable a satisfactory result to be obtained.

I have also given in Table No. 5, the horse power required to overcome the inertia of the trains whose velocity has been calculated in Table No. 1.

TABLE No. 5.

	Tractive Force 2000 lbs.	Tractive Force 2500 lbs.	Tractive Force 3000 lbs.	Tractive Force 3500 lbs.	Tractive Force 4000 lbs.
	Train of 25 Tons.				
Calculated extreme velocity.........	101.12	114.43	126.15	136.0	147.10
Total horse power excited	640.00	800.00	960.00	1120.0	1280.00
Horse power excited in acceleration	576.00	736.00	896.00	1056.0	1216.00
Total horse power per minute	269.00	382.70	505.20	636.3	785.20
Horse power per minute excited in acceleration.	242.00	352.10	471.50	600.0	746.00
	Train of 50 Tons.				
Calculated extreme velocity.........	67.41	77.24	85.90	93.87	101.10
Total horse power excited	640.00	800.00	960.00	1120.00	1280.00
Horse power excited in acceleration	512.00	672.00	832.00	992.00	1152.00
Total horse power per minute	179.70	258.06	344.08	439.20	589.80
Horse power per minute excited in acceleration.	143.80	216.70	298.20	389.04	530.80
	Train of 75 Tons.				
Calculated extreme velocity.........	51.49	59.92	67.40	74.04	80.20
Total horse power excited	640.00	800.00	960.00	1120.00	1280.00
Horse power excited in acceleration	448.00	608.00	768.00	928.00	1088.00
Total horse power per minute	137.30	200.00	269.60	345.60	428.90
Horse power per minute excited in acceleration.	96.13	152.00	215.70	286.40	363.80
	Train of 100 Tons.				
Calculated extreme velocity.........	41.28	49.13	55.86	61.88	67.38
Total horse power excited	640.00	800.00	960.00	1120.00	1280.00
Horse power excited in acceleration	384.00	544.00	704.00	864.00	1024.00
Total horse power per minute	110.30	166.60	223.70	289.40	359.50
Horse power per minute excited in acceleration.	66.20	113.30	164.10	223.20	287.60
	Train of 150 Tons.				
Calculated extreme velocity.........	27.50	35.06	41.20	46.52	51.46
Total horse power excited	640.00	800.00	960.00	1120.00	1280.00
Horse power excited in acceleration	256.00	416.00	576.00	736.00	896.00
Total horse power per minute	73.30	116.70	165.50	219.60	274.60
Horse power per minute excited in acceleration.	29.40	60.70	99.30	144.30	192.20
	Train of 200 Tons.				
Calculated extreme velocity.........	16.80	25.62	31.50	36.68	41.22
Total horse power excited	640.00	800.00	960.00	1120.00	1280.00
Horse power excited in acceleration	128.00	288.00	448.00	608.00	768.00
Total horse power per minute	44.70	84.20	126.30	171.50	219.90
Horse power per minute excited in acceleration.	8.90	30.30	58.90	93.10	131.80

It is necessary now to explain, in order to show the application of the above Tables, that the object in the first instance of the investigation was to ascertain the greatest amount of traffic which could be carried on a single atmospheric line, assuming the mechanical difficulties of leakage, &c., to be overcome.

In order to determine this point, it was necessary to investigate how far the imperfection of the machinery influenced the present results obtained on the line, and how far they were due to the laws of motion, because the former might be corrected, and it would not be safe to found an opinion upon the practical working alone of a new mode of traction, necessarily in an imperfect state.

The actual velocities with various trains have therefore been estimated, assuming no loss at all to occur; and it will be seen that, in a line with frequent stoppages, the time required to overcome so often the inertia of the train will prevent the possibility of the ordinary traffic of a railway being carried on at all times.

The section of a 15-inch pipe produces a moving force so small compared with the weight of an ordinary train, that it takes much longer to put it in motion than a locomotive engine.

The first impression on this point, with reference to the atmospheric system, is, that by avoiding the weight of the locomotive it would have sooner put a train into speed; and this advantage was so boldly stated by its advocates, that the Author fell into the same opinion without examining into the question.

The rate of acceleration depends on the ratio of the

tractive force to the load moved, and with three or four carriages the acceleration will be greater on an atmospheric railway; but with an ordinary train, from the tractive force of a locomotive being equal to double a 15-inch pipe, the acceleration is greater until the velocity is sufficient to reduce the tractive force of the engine; the atmospheric pipe will then have the advantage in speed, as has been seen by the racing of the trains on the Croydon Line, and will undoubtedly produce a much higher speed than the locomotive, and with a more steady and pleasant motion.

RESISTANCE OF THE AIR.

The amount of resistance to trains in moving through the atmosphere, has been a subject of difference of opinion with engineers, in consequence of the difficulty of ascertaining it with any degree of precision at high velocities, in a train propelled by locomotive power, because the amount of reduction of the tractive power of the engine, which is known to arise, has not been ascertained with any degree of accuracy.

The atmospheric railway affords the means of ascertaining the resistance with considerable accuracy, because the tractive force being constant at different velocities, the amount of resistance can be calculated either by the acceleration on a given length of line of a known inclination, or by obtaining the maximum speed with trains of various weights.

On the Dalkey Line, the length for acceleration was not sufficient to obtain a maximum speed so as to obtain a calculated result, but the amount of accelerat-

ing force due to the increase of velocity on different planes can be ascertained and compared with the calculated tractive force on the piston, assuming no friction of the piston to exist, the difference representing the total loss from friction of the piston, resistance of the air, &c.

The moving force due to the observed velocity may be found at once from the equation,

$$V = 2\sqrt{\frac{\left(A P - \frac{T}{I} - \frac{T}{2240} f\right)}{T} S \, 16\tfrac{1}{3}},$$

or if we call the moving force A

$$V = 2\sqrt{\frac{A S \, 16\frac{1}{3}}{T}}$$

from whence we obtain $A = \dfrac{T V^2}{S \, 65\frac{1}{3}}$

In the following Table is given the moving force due to the observed velocities on each of the planes on the Dalkey Line :—

TABLE No. 6.

Length of Plane Twenty-seven Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force, or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	19.3	1 in 166	...	20.0	1705	552.5	1008.35	456.30
12	45.5	21.0	1 in 166	...	17.2	1855	531.7	876.4	344.7
15	53.5	22.7	1 in 166	...	15.0	2005	480.6	854.7	374.1
16	55.8	21.0	1 in 166	...	12.9	1855	369.5	655.9	286.4
17	58.0	24.4	1 in 166	...	15.0	2156	520.7	907.9	387.2
19	63.2	24.1	1 in 166	...	13.4	2138	465.6	770.4	304.8
20	64.7	23.2	1 in 166	...	12.0	2048	572.9	657.0	284.1
	53.6				15.1				
					Mean Loss of Accelerating Force				348.7

Length of Plane Ten Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity, &c.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.5	1 in 104	21.2	22.5	1810.15	...	785.0	785.0
12	45.5	22.4	1 in 104	20.0	20.0	1978.0	...	633.9	·633.9
15	53.5	23.6	1 in 104	16.4	19.0	2083.8	...	...	...
16	55.8	22.2	1 in 104	13.4	13.4	1960.4	—170.7	312.4	483.1
17	58.0	24.5	1 in 104	16.4	17.2	2163.3	...	450.0	450.0
19	63.2	24.1	1 in 104	14.4	15.0	2128.0	128.6	261.2	132.6
20	64.7	24.5	1 in 104	13.4	12.9	2163.0	—197.9	252.0	449.9
	53.6			16.4	17.1				
					Mean Loss of Accelerating Force				467.7

Length of Plane Eight Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force, or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.6	1 in 218	20.0	21.2	1818.98	235.5	1184.83	949.33
12	45.5	22.4	1 in 218	17.2	20.0	1977.9	502.0	1146.42	644.42
15	53.5	23.6	1 in 218	15.0	16.4	2083.8	317.7	1106.4	788.7
16	55.8	22.1	1 in 218	12.9	13.4	1951.3	118.3	931.7	813.4
17	58.0	24.7	1 in 218	15.0	16.4	2181.0	344.4	1121.1	776.7
19	63.2	24.2	1 in 218	13.4	14.4	2136.0	241.3	975.0	733.7
20	64.7	24.5	1 in 218	12.0	13.4	2163.0	219.5	981.0	761.5
	53.6			15.1	16.4				
					Mean Loss of Accelerating Force				780.82

Length of Plane Four Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity, &c.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.5	1 in 139	22.5	22.5	1810.0	...	973.4	973.4
12	45.5	22.5	1 in 139	20.0	20 0	1986.0	...	889.55	889.55
15	53.5	23.7	1 in 139	19.0	17.2	2092.0	...	802.5	802.5
16	55.8	22.3	1 in 139	13.4	14.4	1970.0	426.1	635.0	208.9
17	58.0	24.3	1 in 139	17.2	17.2	2145.0	...	747.0	747.0
19	63.2	24.0	1 in 139	15.0	13.9	2119.0	—589.7	595.2	1184.9
20	64.7	24.5	1 in 139	12.9	13.4	2163.0	—219 5	602.8	822.3
				17.1	16.9				
					Mean Loss of Accelerating Force				804.17

TABLE No. 6. (*Continued.*)

Length of Plane Eight Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.4	1 in 100	22.5	25.7	1801	736.	746.4	10.4
12	45.5	22.5	1 in 100	20.0	21.2	1986	...	603.5	603.5
15	53.5	23.7	1 in 100	17.2	18.0	2092	...	466.3	466.3
16	55.8	22.4	1 in 100	14.4	13.9	1979	— 118.3	282.7	401.0
17	58.0	24.2	1 in 100	17.2	17.2	2136	— 221.4	373.3	594.7
19	63.2	23.9	1 in 100	13.9	14.4	2110	— 160.8	189.0	349.8
20	64.7	24.4	1 in 100	13.4	13.4	2154	— 109.7	188.0	297.7
	53.6			16.9	17.7				
					Mean Loss of Accelerating Force				389.0

Length of Plane Twelve Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.4	1 in 131	25.7	25.7	1801	274.8	930.2	655.4
12	45.5	22.5	1 in 131	21.2	24.0	1986	527.7	844.7	317.0
15	53.5	23.8	1 in 131	18.0	19.0	2101	196.7	758.7	562.0
16	55.8	22.6	1 in 131	13.9	15.0	1995	236.7	592.0	355.3
17	58.0	24.0	1 in 131	17.2	18.0	2119	147.6	663.2	515.6
19	63.2	23.5	1 in 131	14.4	15.7	2075	232.3	490.0	257.7
20	64.7	24.4	1 in 131	13.4	13.9	2154	164.6	530.6	366.0
	53.6			17.7	18.7				
					Mean Loss of Accelerating Force				432.6

Length of Plane Six Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the beginning of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.3	1 in 211	25.7	27.7	1792	706.6	1146.5	439.9
12	45.5	22.6	1 in 211	24.0	24.0	1996	566.2	1149.6	583.4
15	53.5	23.9	1 in 211	19.0	20.0	2110	393.4	1114.2	720.8
16	53.8	22.9	1 in 211	15.0	15.0	2022	— 220.9	983.6	1204.5
17	58.0	24.0	1 in 211	18.0	18.0	2119		1039.4	1039.4
19	63.2	23.3	1 in 211	15.7	15.0	2057	214.4	881.0	666.6
20	64.7	24.4	1 in 211	13.9	13.9	2154	— 182.9	950.5	1133.4
	53.6			18.7	19.1				
					Mean Loss of Accelerating Force				826.0

Length of Plane Twenty-four Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the beginning of the Plane.	Observed Velocity at the end of the Plane.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.0	1 in 115	27.7	30.0	1766	215.9	812.5	596.6
12	45.5	22.6	1 in 115	24.0	27.7	1996	411.7	746.3	334.6
15	53.5	24.0	1 in 115	20.0	24.0	2119	431.3	649.0	217.7
16	55.8	23.4	1 in 115	15.0	20.0	2066	347.2	533.4	186.2
17	58.0	23.8	1 in 115	18.0	21.2	2101	237.8	508.0	270.2
19	63.2	21.3	1 in 115	15.0	15.7	1880	62.5	144.1	81.6
20	64.7	24.4	1 in 115	13.9	18.0	2154	292.7	377.0	84.3
				19.1	22.4				
					Mean Loss of Accelerating Force				252.3

From the examination of the preceding Table it is evident, from the irregularity which exists in the results, that no law can be deduced as to the ratio of the increase of resistance with increased velocities. It is, however, apparent that the resistance from the atmosphere in a quiescent state must be inconsiderable within the velocities obtained in the experiments; for, if an average is taken of the whole of the results, it does not give a loss of tractive force of 10 lbs. per ton on the average weight of trains, including also the loss from friction of the piston.

It is difficult to separate the proportion due to the friction of the piston, but an approximation can be arrived at by comparing the resistance on the first plane, where the velocities are inconsiderable, with the average of the remainder, from which it appears that it amounts to about 250 lbs., leaving 5 lbs. per ton due to the resistance of the air.

As the velocities upon which the calculations are founded are derived from two observations only, which could not be registered with sufficient minuteness to insure a uniform variation of velocity, another Table is given, in which the calculations are founded on the time in passing over the whole plane, by which the irregularity observable in the 1st Table is very much diminished.

TABLE No. 7.

Length of Plane Twenty-seven Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	19.3	1 in 166	...	20.0	1705	552.5	1008.5	456.30
12	45.5	21.0	"	...	17.2	1855	531.7	876.4	344.7
15	53.5	22.7	"	...	15.0	2005	480.6	854.7	374.1
16	55.8	21.0	"	...	12.9	1855	369.5	655.9	286.4
17	58.0	24.4	"	...	15.0	2156	520.7	907.9	387.2
19	63.2	24.1	"	...	13.4	2138	465.6	770.4	304.8
20	64.7	23.2	"	...	12.0	2048	372.9	657.0	284.1
	53.6				15.1				
					Mean Loss of Accelerating Force				348.7

Length of Plane Ten Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.5	1 in 104	21.2	23.8	1810.15	459.3	785.0	325.7
12	45.5	22.4	"	20.0	19.64	1978.0	— 66.4	633.9	700.3
15	53.5	23.6	"	16.4	18.2	2083.1	384.4	503.5	122.1
16	55.8	22.2	"	13.4	14.98	1960.4	246.2	312.4	66.2
17	58.0	24.5	"	16.4	17.8	2163.3	314.9	450.0	125.1
19	63.2	24.1	"	14.4	15.1	2128.0	171.5	261.2	89.7
20	64.7	24.5	"	13.4	13.46	2163.3	21.9	252.0	230.1
	53.6			16.4	17.56				
							Mean Loss of Accelerating Force		238.4

Length of Plane Eight Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.6	1 in 218	20.0	21.14	1818.9	221.2	1184.83	963.63
12	45.5	22.4	"	17.2	19.72	1977.9	612.1	1146.42	534.32
15	53.5	23.6	"	15.0	16 56	2083.8	363.1	1106.4	743.3
16	55.8	22.1	"	12.9	13.7	1951.3	189.3	931.7	742.4
17	58.0	24.7	"	15.0	16.7	2181.0	442.2	1121.1	678.9
19	63.2	24.2	"	13.4	15.94	2136.0	670.3	975.0	304.7
20	64.7	24.5	"	12.0	13.98	2163.0	466.7	981.0	514.3
	53.6			15.1	16.82				
					Mean Loss of Accelerating Force				640.22

Length of Plane Four Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.5	1 in 139	22.5	22.5	1810	...	973.4	973.4
12	45.5	22.5	"	20.0	20.0	1986	...	889.55	889.55
15	53.5	23.7	"	19.0	15.28	2092	—190.6	802.5	2708.5
16	55.8	22.3	"	13.4	14.28	1970	331.5	635.0	303.5
17	58.0	24.3	"	17.2	17.08	2145	— 49.2	747.0	796.2
19	63.2	24.0	"	15.0	13.04	2119	—965.6	595.2	1560.8
10	64.7	24.5	"	12.9	14.16	2163	658.7	602.8	—55.9
	53.6			17.1	16.62				
							Mean Loss of Accelerating Force		1025

TABLE No. 7, *continued*.

Length of Plane Eight Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.4	1 in 100	22.5	25.5	1801	706.6	746.4	39.8
12	45.5	22.5	"	20.0	22.8	1986	770.3	603.5	—166.8
15	53.5	23.7	"	17.2	18.44	2092	340.4	466.3	125.9
16	55.8	22.4	"	14.4	13.8	1979	—118.0	282.7	400.7
17	58.0	24.2	"	17.2	17.2	2136	...	373.3	373.3
19	63.2	23.9	"	13.9	15.5	2110	428.9	189.0	—239.9
20	64.7	24.4	"	13.4	13.76	2154	82.3	188.0	101.7
	53.6			16.9	18.1				
				Mean Loss of Accelerating Force					90.6

Length of Plane Six Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.3	1 in 211	25.7	27.2	1792	549.7	1146.5	596.8
12	45.5	22.6	"	24.0	23.0	1996	—386.6	1149.6	1535.6
15	53.5	23.9	"	19.0	19.56	2110	208.19	1114.2	906.0
16	55.8	22.9	"	15.0	15.5	2022	157.8	983.6	825.8
17	58.0	24.0	"	18.0	18.0	2119	...	1039.4	1039.4
19	63.2	23.3	"	15.7	13.5	2057	—714.9	881.0	1504.9
20	64.7	24.4	"	13.9	14.5	2154	219.5	950.5	731.0
	53.6			18.7	18.75				
						Mean Loss of Accelerating Force			1032.9

Length of Plane Twelve Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per Ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.4	1 in 131	25.7	23.3	1801	—372.9	930.2	1303.1
12	45.5	22.5	"	21.2	22.88	1986	303.8	844.7	535.9
15	53.5	23.8	"	18.0	18.0	2101	...	758.7	758.7
16	55.8	22.6	"	13.9	14.66	1995	126.2	595.0	468.8
17	58.0	24.0	"	17.2	17.6	2119	82.0	663.0	581.2
19	63.2	23.5	"	14.4	14.94	2075	71.49	490.0	418.5
20	64.7	24.4	"	13.4	13.46	2154	...	530.6	530.6
	53.6			17.7	17.83				
				Mean Loss of Accelerating Force					656.6

Length of Plane Twenty-four Chains.

Number of Experiment.	Weight of Train in Tons.	Mean Vacuum.	Inclination of the Plane.	Observed Velocity at the commencement of the Plane.	Velocity at the end of the Plane, calculated from time.	Total Tractive Force of Piston.	Accelerating Force or Pressure on the Piston, deduced from observed Velocity.	Calculated Accelerating Force or Pressure on the Piston, assuming 8 lbs. per ton Loss from Friction, &c.	Difference or Loss of Tractive Power.
7	34.7	20.0	1 in 115	27.7	30.1	1766	215.9	812.5	596.6
12	45.5	22.6	"	24.0	28.04	1996	444.0	746.3	302.3
15	53.5	24.0	"	20.0	23.18	2119	332.9	649.0	316.1
16	55.8	23.4	"	15.0	20.8	2066	544.6	533.4	— 11.2
17	58.0	23.8	"	18.0	23.2	2101	574.3	508.0	— 66.3
19	63.2	21.3	"	15.0	17.8	1880	268.1	144.1	—124.0
20	64.7	24.4	"	13.9	19.42	2154	548.9	377.0	—171.9
	53.6			19.1	23.2				
						Mean Loss of Accelerating Force			120.2

The experiments made by the British Association are certainly very interesting, and evidently taken with great judgment and care, and afford very useful data; but the velocities which could be obtained on the inclines were not sufficiently high, and the experiments not sufficiently numerous, to enable us to arrive at the law; in fact, from the sensible effect which a slight wind makes on the resistance of a train, it requires the average of a great number of results to ascertain the resistance with any degree of satisfaction.

The general abstracts of the results of these experiments are given below in order to compare them with those obtained from the Dalkey Line, which, it will be seen, indicate a much less resistance; a result which will be seen, by a further investigation of the subject, to be nearer the truth in practice.

TABLE No. 8.

EXPERIMENTS MADE BY THE BRITISH ASSOCIATION.

Speed in Miles per Hour.	Train.		Excess per Ton of Load.
	Number of Carriages.	Weight.	
		Tons.	Pounds.
19.20	4	20.45	0.45
19.50	8	40.45	0.45
20.54	8	40.45	3.31
22.50	3	14.8	2.22
22.80	4	20.45	4.65
26.16	3	14.8	6.07
25.40	8	40.45	4.65
25.86	8	40.45	4.25
29.60	3	14.8	10.26
29.31	6	30.45	7.25
29.61	8	40.45	6.65
34.88	4	20.45	9.18
35.58	6	30.45	10.48
37.34	4	20.45	13.46

TABLE No. 9.

EXPERIMENTS MADE BY THE BRITISH ASSOCIATION.

No.	Description of Train.	Weight.	Frontage.	Wind.	Speed.	Total Resistance.	Resistance per Ton.	Friction by Computation.	Friction per Ton.	Resistance of the Air.	Observations.
		Tons.	Square Feet.		Miles per hour.	lbs.	lbs.	lbs.	lbs.	lbs.	
1	Five waggons loaded with bricks.	31.31	24.0	Not observed.	12.5	272.0	8.69	<205	<6.6	> 67	Approximation from experiments by M. de Pambour.
2	Same train	25.58	24.0	Not observed.	13.0	234.5	9.17	<130.7	<5.11	<104	
3	Four first-class coaches	18.05	61.0	Favourable.	33.72	421.0	23.33	100.68	5.58	321.68	
4	Same train	15.6	61.0	Favourable.	31.2	364.0	23.33	95.75	6.14	268.25	The same carriages as in last experiment, but having been lightened by throwing out a quantity of iron chairs with which they had been loaded.
5	Five merchandise waggons constructed with high sides, so as to present an enlarged frontage.	30.0	47.8	Adverse.	17.0	377.0	12.6				
6	Same train with sides lowered	30.0	23.8	Adverse.	22.75	337.0	12.6				
7	Same train with high sides.	30.0	47.8	Adverse.	8.5	255.0	8.5				
8	Same train with sides lowered	30.0	23.8	Adverse.	19.5	255.0	8.5				
9	Same train with high sides ...	30.0	47.8	Adverse.	0.0	204.0	> 6.8	...	...	...	Train came to rest while descending a gradient of 1 in 330.
10	Same train with sides lowered	30.0	23.8	Adverse.	3.0	204.0	> 6.8				
11	One first-class coach, A, and three second-class coaches, B, C, D, loaded.	18.0	61.0	Favourable.	21.0	226.8	12.6	98.64	5.48	128.16	Friction deduced from a comparison of this with Experiment 3.
	Same train	18.0	61.0	Favourable.	21.5	226.8	12.6				
12	One first-class coach, A, and one second-class coach, B.	9.0	61.0	Favourable.	13.9	113.4	12.6				
13	Two second-class coaches, C, D	9.0	61.0	Favourable.	13.5	113.4	12.6				
14	One first-class coach, A, and three second-class coaches, B, C, D.	18.0	61.0	Favourable.	19.5	> 151.6	> 8.4				
15	One first-class coach, A	4.5	61.0	Favourable.	8.5	> 56.7	> 12.6	...	...	...	The variations of speed in the experiments with single coaches showed sensible effects from the wind. The small amount of the resistance of the coach C probably arose from this cause.
16	One second-class coach, B ...	4.5	61.0	Favourable.	12.8	> 56.7	= 12.6				
17	One second-class coach, C ...	4.5	61.0	Favourable.	16.6	= 56.7	> 12.6				
18	One second-class coach, D ...	4.5	61.0	Favourable.	11.9	> 56.7	> 12.6				
19	One second-class coach, C ...	4.5	61.0	Favourable.	12.8	= 38.0	= 8.4				

The experiments subsequently made by them in 1841, to ascertain the effect of the resistance of an engine without its machinery, and that of altering the shape of the end of the carriage, are equally useful and interesting, and decide the point as to the result in the first experiment being incorrect from the resistance of the square end of the carriage; but still it will be seen that the resistance indicated in these experiments at the high velocities is more than would be indicated in practice by the traction of the trains experimented on, arising probably from the front carriage, which receives most resistance, being propelled by those behind in descending a plane by gravity, by which an oscillation is produced, which caused an increased resistance from friction.

The resistance to trains in windy weather is known to all having the management of railway traffic to be very great, and from this an inference has been drawn of the great effect of atmospheric resistance at high velocities. This, it will be seen, is in a great measure an erroneous conclusion, the resistance in windy weather being generally from a side wind, which causes increased friction of the flanches of the wheels against the rails; and this view of the case is confirmed by my own observations, that the effect of a side wind in retarding a train is very much greater than a head wind.

The experiments formerly on the Croydon Atmospheric line enable us to arrive at the resistance at high velocities with more precision than has hitherto been done; and some results were obtained by me, in order to assist the investigation of this subject.